

1-2 Electrostatics: Potential Energy and Electric Potential (Voltage)

Energy is related to work.

Difference in potential energy = work done moving from one point to another.

Voltage or Potential is energy per unit charge.

E_e is electrostatic energy

E is electric field strength $E = F_e/q$

V is potential $V = E_e/q$

Gravity	Electrostatics
<p>Force between masses</p> <p>$F_g = GMm/r^2 = mg$</p> <p>Use GMm/r^2 where g is not constant</p> <p>Use mg if g is constant</p>	<p>Force between charges</p> <p>$F_e = kQq/r^2 = Eq$</p> <p>Use kQq/r^2 for point charges</p> <p>Eq for E is constant</p>
<p>$E_g = -GMm/r$</p> <p>Relative to $E_g = 0$ at $r = \text{infinity}$</p> <p>$= mgh$</p> <p>Relative to any point</p>	<p>$E_e = kQq/r$ (not negative because the force is repulsive) relative to 0 at infinity</p> <p>$\Delta E_e = -qEd$ energy moving a charge q in the direction of</p>

	an electric field E through a displacement d (negative because the field is pulling the positive charge in the direction of the field)
	$V = E_e/q = kQ/r$ $\Delta V = -Ed$

Eg. 1. An electron jumps from an orbital a distance $1.0 \times 10^{-10}\text{m}$ to $5.0 \times 10^{-11}\text{m}$ from a proton.

- What is the electrostatic potential energy of the electron in each position relative to 0 at infinity?
 - What is the voltage at each orbital?
 - What is the potential difference between the outer and inner orbital?
 - What is the energy of the released photon? (energy difference)
2. Two parallel plates are 0.50 cm apart and connected to a 9.0V battery.
- What is the electric field strength between the plates?
 - How much energy is required to move an electron from the negative plate to the positive

plate?

c) How much work is done moving a proton 0.20 cm towards the positive plate?

$e = 1.602 \times 10^{-19} \text{ C}$ (magnitude of the charge of proton or electron)

$$1a) E_e = kQq/r = 9.0 \times 10^9 \text{ Nm}^2/\text{C}^2 (1.6 \times 10^{-19} \text{ C}) (-1.6 \times 10^{-19} \text{ C}) / 1.0 \times 10^{-10} \text{ m}$$

$$E_e = -2.3 \times 10^{-18} \text{ J} \text{ and } -4.6 \times 10^{-18} \text{ J}$$

$$b) V = E_e/q = -2.3 \times 10^{-18} \text{ J} / -1.6 \times 10^{-19} \text{ C} = 14 \text{ V}$$

A volt is the unit of electric potential $V = \text{J/C}$

And 28V

$$c) \text{ Difference} = V_f - V_i = 28\text{V} - 14\text{V} = 14\text{V}$$

$$d) \text{ Energy} = 14\text{eV} = 2.3 \times 10^{-18} \text{ J}$$

$$\text{eV is a unit of energy} = 1\text{eV} = 1.6 \times 10^{-19} \text{ J}$$

$$\text{(keeners } E = hf \text{ } f = 2.3 \times 10^{-18} \text{ J} / 6.6 \times 10^{-34} \text{ Js} = 3.5 \times 10^{15} \text{ Hz} \text{ wavelenth} = v/f = 3.0 \times 10^8 \text{ m/s} / 3.5 \times 10^{15} \text{ Hz} = 8.6 \times 10^{-8} \text{ m} \text{ ultraviolet light})$$

2.

1-1 Electrostatics

Electrostatic Potential Energy, E_e

Electrostatic Potential (Voltage), V

Energy is the ability to do work. We can derive our energy equation from $W=Fd$ or the area under an $F - d$ graph, just like gravity.

Gravity	Electrostatics
Pull between all masses, m or M in kg	Push or pull between all charges, q or Q in C
$F_g = GMm/r^2$ between any 2 masses	$F_e = kQq/r^2$ between any 2 charges
$F_g = mg$ if g is uniform and known	$F_e = Eq$ if the electric field strength, E , is given or is uniform (parallel plates)
Einstein curvature of space time	Feynman - transfer of bundles of energy
$E_g = mgh$ if g is uniform	$\Delta E_e = -qEd$ where q is the charge, E is electric field and d is the displacement the charge moves in the direction of the field.
$E_g = -GMm/r$	$E_e = kQq/r$ (not negative)

The work to bring mass m from infinity to r	because force is repulsive) The work to bring q from infinity to r
	Define electric potential (Voltage) $V = E_e/q$
	Potential difference $\Delta V = -Ed$ (if d is in the direction of the field) $V = kQ/r$

Eg. A $1.0 \mu\text{C}$ charge is 0.50 m from a $2.0 \mu\text{C}$ charge.

a) What is the electrostatic potential energy of the $1.0 \mu\text{C}$ charge?

$E_e = kQq/r = 9.0 \times 10^9 (2.0 \times 10^{-6}\text{C})(1.0 \times 10^{-6}\text{C}) / 0.50 \text{ m} = 0.036 \text{ J}$ relative to 0 at infinity

b) What is the potential at the $1.0 \mu\text{C}$ charge?

$V = E_e/q = 0.036 \text{ J} / 1.0 \times 10^{-6}\text{C}$
 $= 3.6 \times 10^{-8}\text{V}$ (unit is volts, $V = \text{J/C}$)

c) How much work is done if the $1.0 \mu\text{C}$ charge is moved 0.20 m closer?

$W = Fd$ if F is constant

$W = \Delta E_e = E_{ef} - E_{ei} = kQq (1/r_f - 1/r_i)$

$$9 \times 10^9 \text{ Nm}^2/\text{C}^2 (2.0 \times 10^{-6} \text{C})(1.0 \times 10^{-6} \text{C}) \\ (1/0.30\text{m} - 1/0.50\text{m}) = 0.024 \text{J}$$

2. Two parallel plates are 0.25 m apart and have a 20.0 V potential difference.

Determine

- a) The electric field between the plates
- b) The kinetic energy gained by an electron moving from the negative plate to the positive plate.

a) $\Delta V = -Ed$

$$E = 20.0 \text{V} / 0.25 \text{m} = 80.0 \text{ N/C}$$

Direction of the electric field, E , is from the high voltage plate (positive plate) to the low voltage plate (negative plate)

b) $\Delta E_e = \Delta E_k = Vq = 20.0 \text{V} \times 1.6 \times 10^{-19} \text{C} \\ = 3.2 \times 10^{-18} \text{J}$

Or 20.0 eV eV is a unit of energy, the electron volt. $1 \text{eV} = 1.6 \times 10^{-19} \text{J}$

Eg. 1. An electron jumps from an orbital a distance $1.0 \times 10^{-10} \text{m}$ to $5.0 \times 10^{-11} \text{m}$ from a proton.

- a) What is the electrostatic potential energy of the electron in each position relative to 0 at

infinity?

- b) What is the voltage at each orbital due to the proton?
 - c) What is the potential difference between the outer and inner orbital?
 - d) What is the energy of the released photon? (energy difference) in eV and in J
2. Two parallel plates are 0.50 cm apart and connected to a 9.0V battery.
- a) What is the electric field strength between the plates?
 - b) How much energy is required to move an electron from the negative plate to the positive plate? In eV and in J.
 - c) How much work is done moving a proton 0.20 cm towards the positive plate?

$e = 1.602 \times 10^{-19} \text{ C}$ (magnitude of the charge of proton or electron)

1-3 Electrostatics

Electric potential energy, E_e

Electric potential (Voltage), V , Emf , ε

Electric field strength, $E = F_e/q$

Energy is the ability to do work, so we can derive energy equations from $W = Fd$ or area

under the F-d graph.

Gravity	Electrostatics
$F_g = GMm/r^2$ the force pulling masses, M and m together.	$F_e = kQq/r^2$ the force pushing or pulling charges, Q and q together or apart.
$F_g = mg$ where g is given or constant	$F_e = Eq$ where E is give or is constant (parallel charged plates)
$E_g = -GMm/r$ relative to 0 at infinty	$E_e = kQq/r$ (not negative because it is repulsive) Relative to 0 at infinity
$E_g = mgh$	$\Delta E_e = -qEd$ work done moving a charge q a distance d in the direction of the field, E
	Define Potential or Voltage as the energy per unit charge $V = E_e/q$
	Potential around a point charge, Q $V = kQ/r$
	$\Delta V = -Ed$ $E = \Delta V/d$ the electric field goes from high voltage(positive) to low voltage(negative).

Eg.1. You have a $1.0 \mu\text{C}$ charge 0.50m from a $2.0 \mu\text{C}$.

a) Find the voltage 0.50 m from the $2.0 \mu\text{C}$ charge.

$$V = kQ/r = 9.0 \times 10^9 \text{Nm}^2/\text{C}^2 \times 2.0 \times 10^{-6}\text{C}/0.50\text{m}$$
$$V = 36\,000 \text{ V} \quad (1\text{V} = \text{J}/\text{C})$$

a) What is the electrostatic energy of the $1.0 \mu\text{C}$ charge at that point relative to 0 at infinity?

$$E_e = kQq/r = Vq = 36\,000 \text{ V} \times 1.0 \times 10^{-6}\text{C} = 0.036\text{J}$$

a) What is the work done moving the $1.0 \mu\text{C}$ charge 0.20 m closer to the $2.0 \mu\text{C}$ charge?

$W = Fd$ only when F is constant

$$W = \Delta E_e = E_{ef} - E_{ei} = kQq(1/r_f - 1/r_i)$$
$$9.0 \times 10^9 \text{Nm}^2/\text{C}^2 (2.0 \times 10^{-6}\text{C})(1.0 \times 10^{-6}\text{C})$$
$$(1/0.30\text{m} - 1/0.50\text{m}) = 0.024\text{J}$$

2. Two parallel plates 0.25 cm apart are connected to a 20.0 V power source. What is the

a) Electric field strength between the plates?

$$E = \Delta V/d = 20.0\text{V}/0.25\text{cm} = 8000 \text{ N/C}$$

a) Kinetic energy given to an electron moving from the negative plate to the positive plate?

In J and eV (1eV = $1.6 \times 10^{-19}\text{J}$)

$$E_k = \Delta E_e = Vq = 20\text{V} e = 20.0 \text{ eV}$$

$$20\text{V} \times 1.6 \times 10^{-19}\text{C} = 3.2 \times 10^{-18} \text{ J}$$